THE EFFECTS OF BACKGROUND CONTRAST ON CONFORMAL MESH MICROWAVE BREAST IMAGING

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***Abstract* -We have developed a prototype saline-coupled microwave breast imaging system with a non-contacting monopole antenna array. We have demonstrated in simulation and phantom experiments that the detection of internal features can be enhanced as the parameter reconstruction mesh approaches the exact breast perimeter. However, in the case of a homogeneous breast phantom we have also observed a centrally located artifact in some recovered images which could be interpreted as a false positive detection in an actual patient examination. Simulation results presented here illustrate that if the electrical property contrast between the background medium and breast is reduced, the conformal meshing approach can be used successfully with only a minimal central artifact while retaining the improved inclusion detection characteristics associated with the conformal mesh technique.**

***Keywords* – Microwave imaging, conformal mesh, breast, background contrast**

I. INTRODUCTION

Because of the high electrical property contrast between normal and malignant breast tissue, microwave imaging may be able to provide clinically significant diagnostic information [1,2]. Our prototype microwave breast imaging system was designed for use with a non-contacting antenna array in a saline bath [3]. Choice of the coupling medium was dictated at the time by cost and convenience since we needed to explore patient interface issues in an actual clinical setting. While the choice of saline was probably not optimal in terms of contrast between the breast and coupling medium, it did allow us to acquire actual patient data with which we could explore a variety of software approaches to improve image reconstruction. The general concept has been to exploit computer analysis to predict what system hardware modifications would be most beneficial.

One of the most promising of these software techniques is the idea of conforming the property reconstruction mesh to the exact breast perimeter. In principle this would allow a property step function to be imposed (our algorithm assumes a homogeneous property distribution outside the region enclosed by the reconstruction mesh) at the breast interface [4]. This also facilitates deployment of the reconstruction parameter nodes to locations within the breast as opposed to space occupied by the coupling medium where the property values are already known. Fundamental issues with regards to actual implementation of this approach in the clinic (primarily identification of the breast perimeter) remain unresolved. In addition, since the breast geometry varies in 3D and the electric fields propagate into 3D space, identification of an effective 2D perimeter is quite complicated. However, preliminary results indicate that modification of the mesh to approximately conform to the breast will still result in considerable image enhancement with respect to inclusion detection.

Unfortunately, recent studies with this enhancement have also shown that when a homogeneous phantom is imaged, an artifact appears in the center of the image that could suggest the presence of a tumor. The artifact seems to become more pronounced as the reconstruction mesh approaches the exact breast perimeter. It is essential to resolve this problem so that our ability to distinguish malignant tissue from the normal breast is not compromised. Interestingly, the results presented here show that when the background/breast contrast is reduced, the central artifact diminishes considerably. The identification of this effect has motivated effort to distill a recipe for the coupling medium that meets these electrical property goals while also satisfying patient and environmental safety requirements without unduly increasing patient exam costs.

II. METHODS

The simulations presented here were performed at 900 MHz for a 15 cm diameter monopole antenna array. The geometry of the breast cross-section was taken to be mildly elliptical in shape with 10 and 8 cm major and minor axes, respectively. It was centered within the array and oriented at 20 degrees with respect to the horizontal axis to accentuate its non-uniform (i.e. not circular) geometry with respect to the image field of view. The reconstruction meshes consisted of (a) 13 × 11 cm ellipse, (b) 12 × 10 cm ellipse, (c) 11 × 9 cm ellipse, and (d) 10 × 8 cm ellipse, with the major axis of each oriented identically to that of the actual breast phantom. The properties used for the breast and tumor inclusion were: ε_r=23, σ=0.18 S/m, and ε_r=57, σ=1.14 S/m, respectively. The conductivity of the background was held constant at 1.7 S/m and the relative permittivities used for the background were: 80, 70, 60, 50, 40 and 30. The initial property estimate for each case was first produced on the forward solution mesh and

Report Documentation Page

Report Date	Report Type	Dates Covered (from... to)
25 Oct 2001	N/A	-

Title and Subtitle The Effects of Background Contrast on Conformal Mesh Microwave Breast Imaging	**Contract Number**
	Grant Number
	Program Element Number
Author(s)	**Project Number**
	Task Number
	Work Unit Number
Performing Organization Name(s) and Address(es) Thayer School of Engineering Dartmouth College Hanover, NH	**Performing Organization Report Number**
Sponsoring/Monitoring Agency Name(s) and Address(es) US Army Research, Development & Standardization Group (UK) PSC 802 Box 15 FPO AE 09499-1500	**Sponsor/Monitor's Acronym(s)**
	Sponsor/Monitor's Report Number(s)

Distribution/Availability Statement
Approved for public release, distribution unlimited

Supplementary Notes
Papers from 23rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society, October 25-28, 2001, held in Istanbul, Turkey. See also ADM001351 for entire conference on cd-rom.

Abstract

Subject Terms

Report Classification unclassified	**Classification of this page** unclassified
Classification of Abstract unclassified	**Limitation of Abstract** UU

Number of Pages
4

subsequently mapped to the parameter reconstruction grid. To accomplish this task, a collection of finite elements in the uniform mesh conforming as closely as possible to the breast were selected to have ε_r=15 and σ=0.25 S/m, with the surrounding finite elements assigned the exact background properties (Fig. 1).

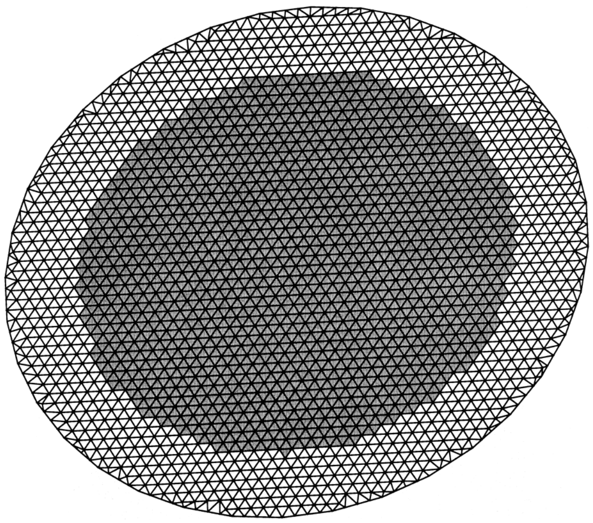

Fig. 1. 13 x 11 ellipse mesh with the initial guess shown as the shaded region. This property distribution is mapped onto the reconstruction parameter mesh during the reconstruction process.

The shape of the selected elements was chosen to be as close to the actual breast shape as possible to minimize the effects of the initial estimate on the final results.

III. RESULTS

Figure 2a shows the sequence of recovered images for the homogeneous breast phantom for the four reconstruction meshes with a high contrast background (ε_r=80). Note that in all cases there is an undesired artifact in the center of the recovered image which appears to degrade with smaller mesh size. For the cases where the mesh is physically larger than the breast, a considerable portion of the image is engaged in representing the steep gradient between the background medium and the breast. Figure 2b shows a similar sequence of images for the same reconstruction meshes but with a much lower background contrast (ε_r=40). It is clear that in all cases, especially for those where the mesh more closely matches the actual breast size, that the artifact is virtually indiscernible. The reduction in contrast has clearly improved the recovery of the homogeneous breast.

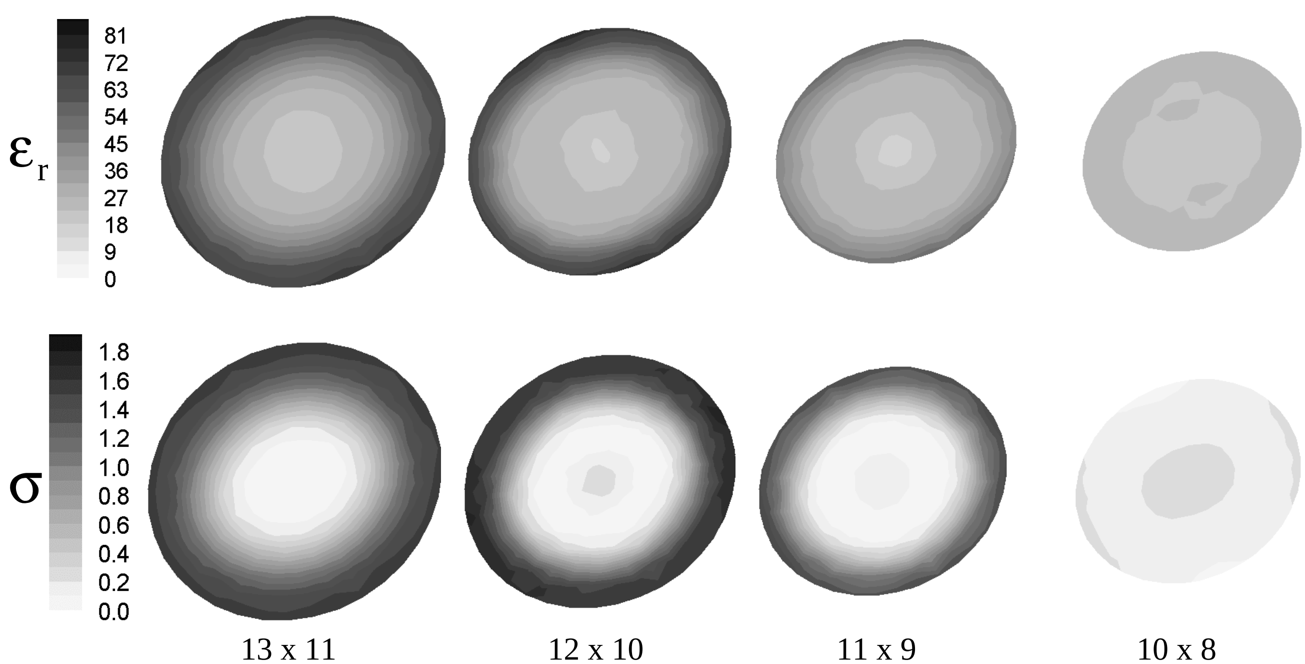

Figure 2a. 900 MHz reconstructed permittivity and conductivity images for a homogeneous elliptical breast cross section with a background medium having ε_r = 80 and σ = 1.7 S/m.

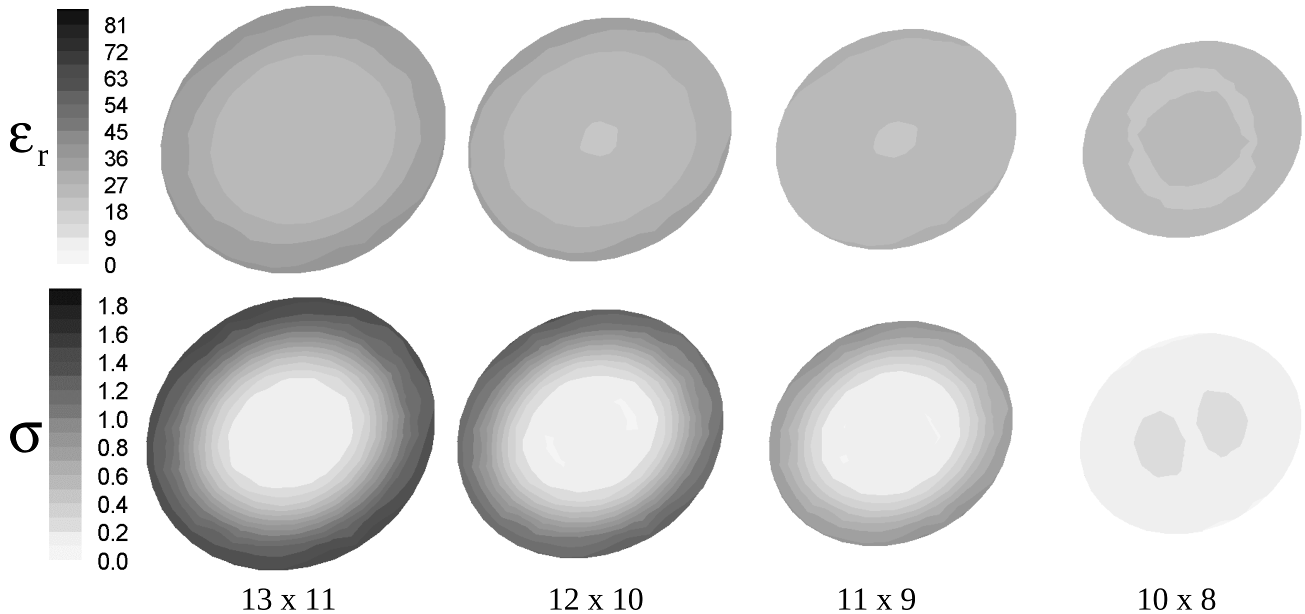

Figure 2b. 900 MHz reconstructed permittivity and conductivity images for a homogeneous elliptical breast cross section with a background medium having ε_r = 40 and σ = 1.7 S/m.

Figures 3a and b show a similar sequence (including the same background contrast values) of images for the same breast except with a 2 cm diameter tumor inclusion. For the physically larger meshes, the inclusion appears as a modest indentation in the breast perimeter, while its recovery using the smaller meshes is far more distinct in terms of position, shape and property values. This improvement is progressive with incremental reductions in background contrast. As in the homogeneous breast case, a large portion of the area surrounding the breast is engaged in recovering the steep property gradient between the breast and background. It also appears, especially for the larger mesh cases, that the algorithm does a better job of recovering the inclusion with the lower background contrast.

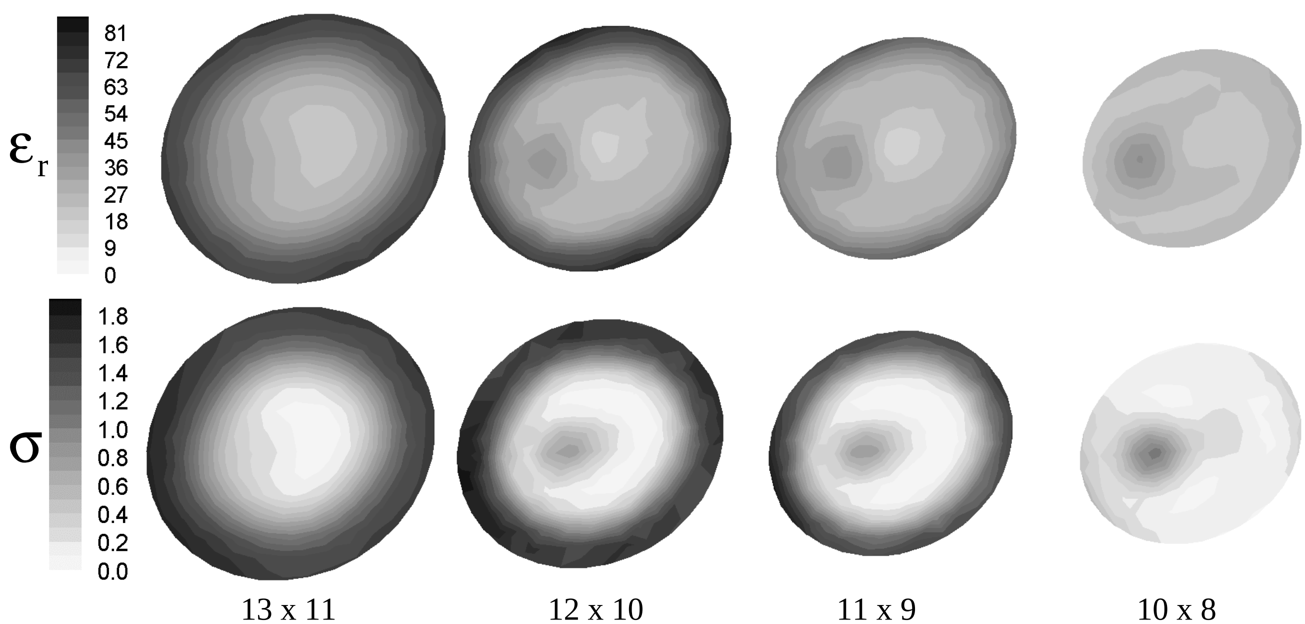

Figure 3a. 900 MHz reconstructed permittivity and conductivity images for an elliptical breast cross section with a 2 cm tumor inclusion and a background medium having ε_r = 80 and σ = 1.7 S/m.

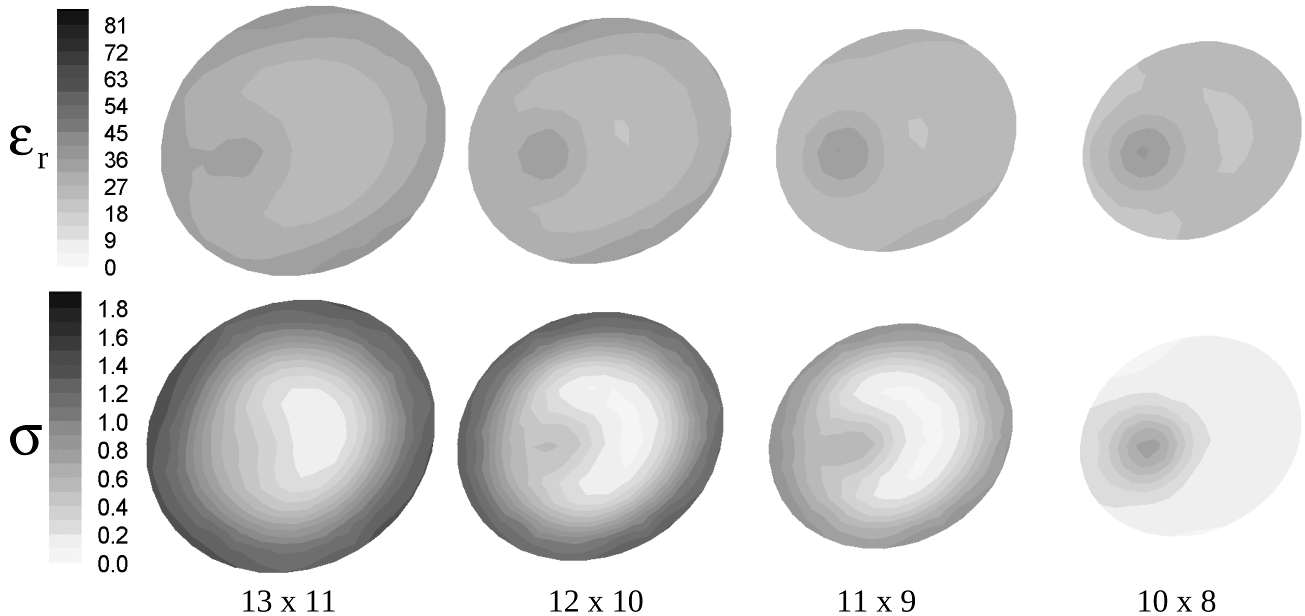

Figure 3b. 900 MHz reconstructed permittivity and conductivity images for an elliptical breast cross section with a 2 cm tumor inclusion and a background medium having ε_r = 40 and σ = 1.7 S/m.

V. CONCLUSION

The conformal mesh approach is a powerful tool in recovering tumor inclusions when utilizing a non-contacting antenna array technique. It appears that there is significant improvement in the ability to detect inclusions even when the reconstruction mesh does not exactly overlay the exact breast, but is slightly larger than its physical extent. However, when the contrast between the coupling medium and breast is sufficiently large, significant image artifacts in the center of the breast may occur and potentially confound the ability to discern benign and malignant conditions. This effect can be diminished to tolerable levels by reducing the contrast in permittivity between background and breast. These results are the prime impetus for renewed investigation into optimal coupling media.

ACKNOWLEDGEMENTS

Sponsored by NIH/NCI grant number: PO1 CA80139.

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